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Effects of land management practices on soil physicochemical properties of selected sites in the Migina catchment, Kansi sector, Gisagara District, southern province of Rwanda

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Abstract**—** *Land use changes from natural ecosystems into managed ecosystems may have impacts on soil structure and quality. Land management practices contribute to the change of soil properties and agriculture production. Rwanda's livelihood and social economy is strongly dependent on agriculture. Moreover, the exponential Rwandan population growth is making a severe pressure on natural resources including forests. In order to contribute to sustainable and environmentally friendly agriculture, the present research focused on the impact of land management on soil quality. Many scholars have proved that even the downhill surface water quality is mainly affected by unsustainable land management practices. This research was carried out to determine the impact of land management on soil quality in order to contribute to its protection and a sustainable agricultural production for food security, soil and water conservation. This study was conducted at Akaboti cell, Kansi Sector, Gisagara District of the Rwandan Southern Province, exactly in the Migina catchment watershed with different agricultural activities for comparison. The following physicochemical characteristics were evaluated: soil reaction (pH), organic carbon, Nitrogen, Phosphorus, Exchangeable basis (Calcium, Sodium, Magnesium, Potassium), exchangeable acidity, soil texture, moisture content, bulk density, and electrical conductivity. The laboratory results showed that soils across the different land management practices were dominated by the soil texture classified as sandy loam textural class. The soil bulk density varied between 0.96 and 1.44 g /cm^{-3}, the soil porosity was 50.2 to 52.08 % in terraced land; 47.2 to 58.16 % in trenches; 53.8 to 63.87 % in agroforestry and 53.08 to 53.8 % in forested land. In general values for this parameter ranged from 56.39 to 58.9 % in managed lands and 45.9 to 51.84% in non-managed land (the control). The soil pH ranged from 4.73 to 5.14 for the radical terraced land, 5.79 to 5.29 for trenches, 6.29 to 5.79 for agroforestry land, 4.49 to 4.93 for forested land, 5.11 to 6.34 for amended soil and 4.69 to 5.27 for the*

control. The electrical conductivity was low in all treatments ranging from 0.076 to 0.39. The values of mineral nitrogen measured in managed lands were higher compared to those measured in the control. Ammonium values ranged from 2.55 to 7.24 mg kg^{-1} while those of nitrate ranged from 4.36 to 28 mg kg^{-1}. Available P values were higher in the managed land than in the control. The values of available P ranged from 8.55 to 17.10 mg kg^{-1}. The values of exchangeable bases were slightly higher in managed land than in control; however, those values were generally low. Generally, the agroforestry land showed high nutrients values compared to the control and other treatments. From the results of this study, it is clear that the land management practices have generally a positive impact on soil properties. Farmers are therefore advised to adopt those practices, especially agroforestry.

***Keywords*— Soil quality parameters, land use changes, soil degradation, Migina catchment.**

I. INTRODUCTION

Land use/land cover (LULC) changes influence the biogeochemistry, hydrology, and climate of the earth (Tellen&Yerima, 2018). The land management has great importance on land productivity, ecosystem function, soil health, environmental protection and social-economic activities (Ruslanjari&Taufan, 2017). Land is one of the natural resources that provides profits and food through agricultural activities. Most people living in Sub- Saharan African depend upon natural resources especially land and water for their livelihoods. Agriculture production supplies a big contribution to the most gross domestic product of Africa (Majule, 2010). Across sub-Saharan Africa, natural resources remain central to rural people's livelihoods (Roe et al., 2009).

In Rwanda, the majority of people rely on agriculture production, which employs over 80% of the population and generates over 40% of the country's GDP (Mbarushimana, J. D. D, 2019). The land management sustainability depends on a combination of different approaches from different perspectives including technologies and policies that integrate socio-economic values for enhancing production. Land management works out issues of both population increasing and natural resources degradation while available agricultural land decreases. Even if land management practice is very important, it is challenged by several factors including climate variation, erosion, overexploitation, overgrazing, population pressure, deforestation, improper land management and other different human activities (Mongi, H., Majule, A. E., &Lyimo, J. G, 2010). The land degradation is influenced by composite interaction among human activities and the environment, wherever it is the permanent or temporary decreasing of the possible productive capability of land resources and for that case the utilization and management of natural resources could be a central issue (Tesfahunegn, G. B, 2019).

As results of land degradations, are manifested by soil erosion, compaction of soil, animal and plant species, soil biota losses, and nutrient depletion, with associated risks to the production sustainability of ecological and food commodities and services (GEF, 2005).

Furthermore, recently few studies have made attention of the interrelation among land management practices and water quality then the lack of information has impaired the sustainability of agricultural productivity, ecosystem functioning and welfare of livelihood of farmers (Paul & Rattan, 2014). Watershed management is being implemented by public and private institutions to improve land use sustainability but unfortunately many rural farmers are not participating in local community activities since they are not involved in practices' decision making as well as insufficient research, lack of skills and financial constraints (Kuria et al., 2018). The poor land management and overexploitation of soil in Migina catchment leads to the soil and water degradation then agricultural productivity decline, removal of vegetation cover, soil erosion acceleration, nutrient depletion and decrease in arable land. To feed the rapidly growing population, it is necessary to improve agricultural productivity in the country; this can be achieved by a change in agricultural practices (Wali, 2014).

The population cultivates even the marginal areas in trying to satisfy their needs in food security and they are growing but the arable land decreases (Olson & Berry, 2003).

Therefore, this study aims to assess the impact of land management practices such as the radical terrace, forest, agroforestry, trenches and soil amendment on soil quality in Migina catchment and we were based on physic-chemical elements that are improving soil fertility for increasing crop productivity.

There are few land management practices that are established in this area but some of them are degraded due to the population's poor management and others are not well established. Then to achieve sustainable agricultural development, the soil restitution of land management activities is needed for soil quality and land productivity improvement. For achieving the increase of agricultural productivity, it is necessary to take care on land

degradation issues for preventing loss of soil nutrients and sustainability of agricultural productivity and then it is very important to reinforce the level and awareness of citizen's participation in the land use management process. This study was released in order to find the equivalent solution to the cited above problem and to enhance land management practice improvement for managing soil quality in Migina Catchment. Specifically, it was based on the result of the difference.

The main purpose of this study was to evaluate the impact of land management on soil quality and the specific objectives being: (1) To characterize the physic-chemical properties of soil under different land use systems which are radical terrace, trenches, forest, agroforestry, soil amendment and a control; (2) To determine the ability of different land management practice for improving soil fertility status compared to fertility standards; (3) Assess the impact of land use systems on properties such as the soil texture, electrical conductivity, bulk density and moisture content improvement. These objectives are established based on the hypothesis that a good land management practice may improve soil quality including chemical nutrients and soil physical properties. The effects of land management practices on physicochemical properties variation is based on the elements that may influence soil fertility status. More researches have proved that there is direct interrelationship between water quality and land use management activities such as deforestation, clustered settlements releasing wastes, erosion due to non-protected slopes, and non-protected river banks. Particularly the study took place in Gisagara District, Kansi Sector at Akaboti Cell where we found our proposed different land management practices in farmer's land. This study was released in order to find the equivalent solution to the cited above problem and to enhance land management practice improvement for managing soil quality in Migina Catchment. The effects of land management practices on physic-chemical properties variation is based on the elements that may influence soil fertility status.

II. MATERIAL AND METHODS

2.1. Description of the study sites

The latest study was performed in the Migina catchment, which is found in Rwanda's Southern Province and passes through Huye, Gisagara and Nyaruguru districts. Our analysis was done within five purposely selected land management practices that are agroforestry, forestry, radical terraces, trenches and soil amendment.

Geographically, Migina catchment is situated between latitudes 2°32' to 2°48' South and with longitudes of 29°40' to 29°48' East, in the southern part of Rwanda. Its mean annual temperature is about 20°C and its mean annual rainfall is 1200 mm/a and then 917 mm/a is estimated to be its mean annual actual evaporation (Munyaneza, O., Mukubwa, A., Maskey, S., Uhlenbrook, S., &Wenninger, J, 2014).

The average altitude of Migina Catchment is 1681 m. Migina catchment is among the Akagera river sub basin and is subdivided into 5 sub-catchments referring to the main draining rivers area, in upstream. Two sub-catchments are located upriver; Munyazi-Rwabuye with about 38.6 km^2 and Mukura with 41.6 km^2; two in the center which are Akagera with 32.2 km^2 and Cyihene-Kansi with 69.6 km^2; and another one also is located in downstream area contains the outlet of the whole catchment: Migina with 61.1 km^2 (Manzi, A., Munyaneza, F., Mujawase, F., Banamwana, L., Sayinzoga, F., Thomson, 2014).

The studied area has a pronounced slope due to hilly and mountainous relief alternated to marshland. The western part has a higher elevation than the eastern part. Towards the south, the hills and elevation becomes lower, with maximum elevations up to 1,900 m. The eastern side of the catchment is relatively low. The river valleys have an elevation of approximately 1,650 m. (Harmenet al. 2010). The topographic conditions are extremely variable, with valley slopes value from 5 to 10% upstream and 1 up to 15% downstream (the average slope of the sub-catchments is between 2 and 3 percent (Kayiranga, A., Ndayisaba, F., Nahayo, L., Karamage, F., Nsengiyumva, J. B., Mupenzi, C., &Nyesheja, E. M, 2017).

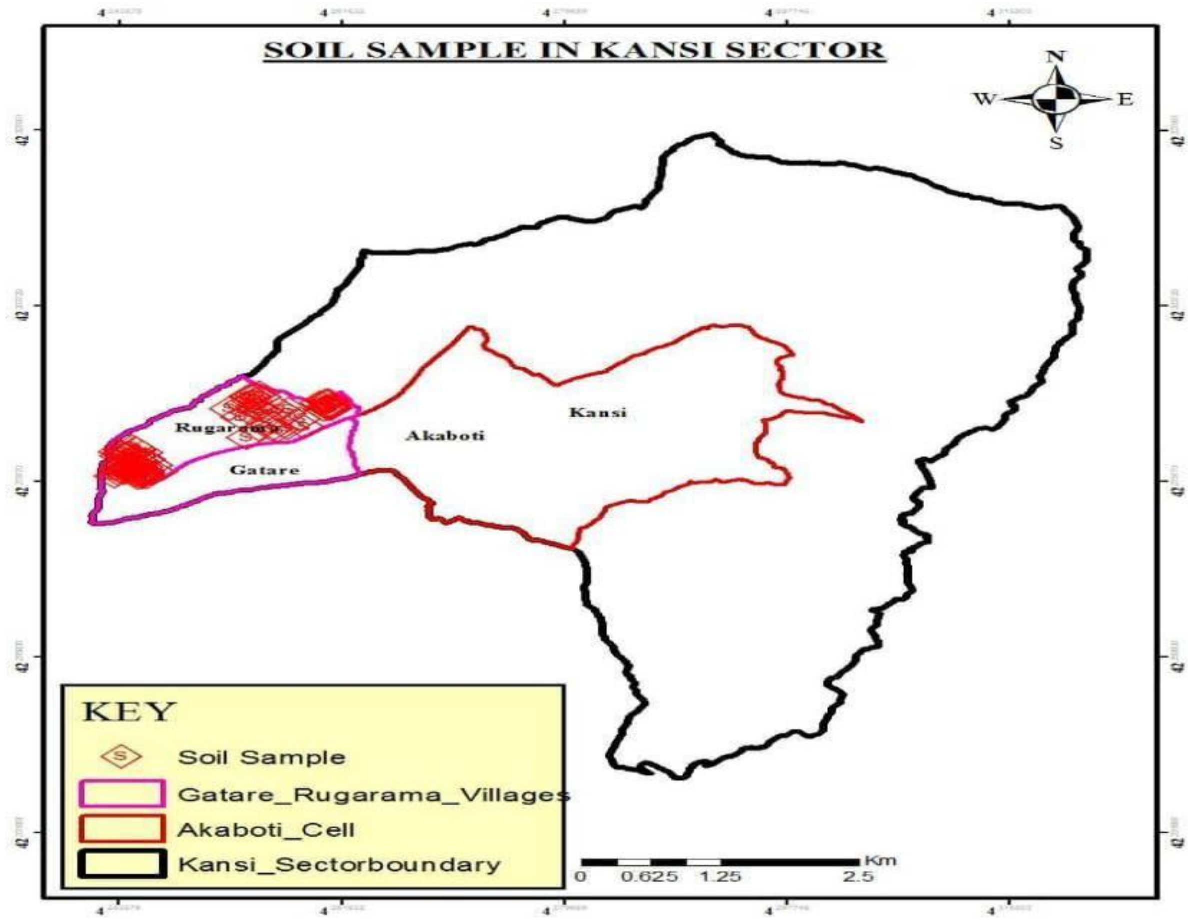

Fig.1: Soil sampling sites inKansi sector, Akaboti cell, Rugarama village

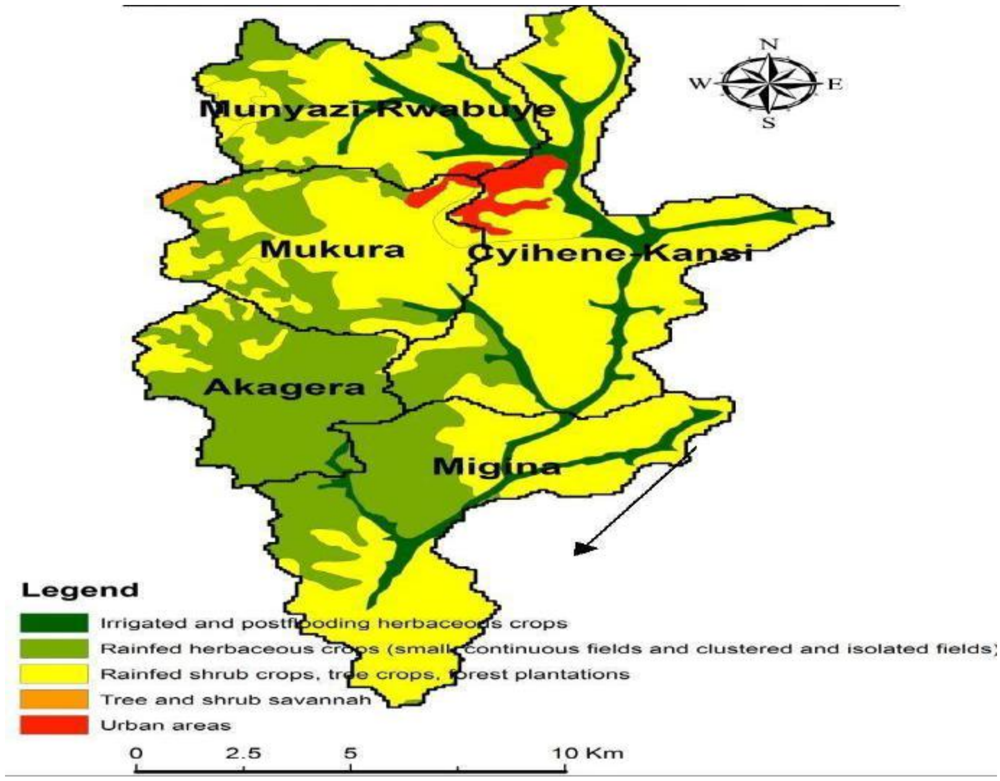

Fig.2: *Land use, sub-catchments and main rivers in the Migina catchment, Source: MINAGRI, 2016*

2.2. Materials

Field and Laboratory equipment

Different materials were used on the field in order to gather soil samples for laboratory analysis comprising Auger, Basket, Cooler box, Coiling, Coiling box, Knife, Hoe, Decameter, Timber and GPS.

- Auger was used for taking a soil sample from different locations of the field (on the Top slope, middle slope, and bottom and Cooler box used to keep cold and fresh soil for available Nitrogen Analysis.
- Coiling and Coiling box was used to take flesh soil and to keep them fresh for soil moisture and bulk density analysis and Basket used to make mixture of composite soil sample for better laboratory analysis
- GPS is an electronic field material that was used to take Geographical Coordinates.

We used appropriate equipment such as pH -meter, stirrer, spectrophotometer, digester, distiller flasks, funnels, pipettes, precision balance, cylinders, filter papers, Erlenmeyer, sieves, watch glass, crucibles, sand bath, spoons, auger, mortar, pestle, Electronic Balance, Volumetric flask, Conical flask, Steam distillation, Micro burette, Mechanical shaker, plastic bottles with stoppers, Magnetic stirrer, Beakers, Hydrometer, Thermometer, etc. and many laboratory chemical product to analyze soil constituent elements. Some more levels of elements existing in soil were determined using AAA (Atomic Absorption Spectrophotometer) which provides an advantage of saving time giving results quickly than other materials. It has been used to analyze Ca, Na, Al and K elements.

2.3. Research methodology

Soil sampling

Stratified soil sampling method using auger was used to collect samples in different land management practices (terraced land, trenches, agroforestry, forestry and control). The sampling was done along a topography sequence (Upland, middle and low land) and simple sites were located by international coordinates using the worldwide positioning system GPS (model GARMIN etrex 20). From each sampling unit, disturbed (bulk) and undisturbed (core samples) the physicochemical analysis in the laboratory used those taken samples.

Gathered samples were 18 composite soil samples collected to a depth of 30 cm, labeled and prepared for analysis.

Laboratory analysis

The laboratory work was done in the soil and plant analysis Laboratory at University of Rwanda. The collected soil samples mean disturbed one were air-dried and ground to pass through a 2 mm and 0.5 mm sieve for laboratory analyses. Without interruption core samples were used for calculating the soil bulk density, moisture content, particle density, porosity and texture.

The core methods were used to determine the bulk density (Black and Hartge, 1986). Particle density of the soil was calculated by determining the mass and volume those particles solid occupy.

The solid particles mass was also determined by measuring the solid particle and the same at the volume was obtained from the weight and water density displacement by soil sample (Blake and Hartge, 1989). Total soil porosity was determined using a formula outlined by NSS (1990) as follows: Soil porosity (Particle density - Bulk density) / Particle density) *100 for every sample.

Those samples of soil that are disturbed were used for analyzing the remaining physical and all chemical properties of soil except available nitrogen (N-NO_3^- and N-NH_4^+) which used flesh soil. Hydrometer method after dispersion with sodium hexametaphosphate 5% (Mbaga, H., &Makoi, J. H, 2018). The textural classes were calculated using the USDA textural class triangle (USDA, 1975) which is illustrated below:

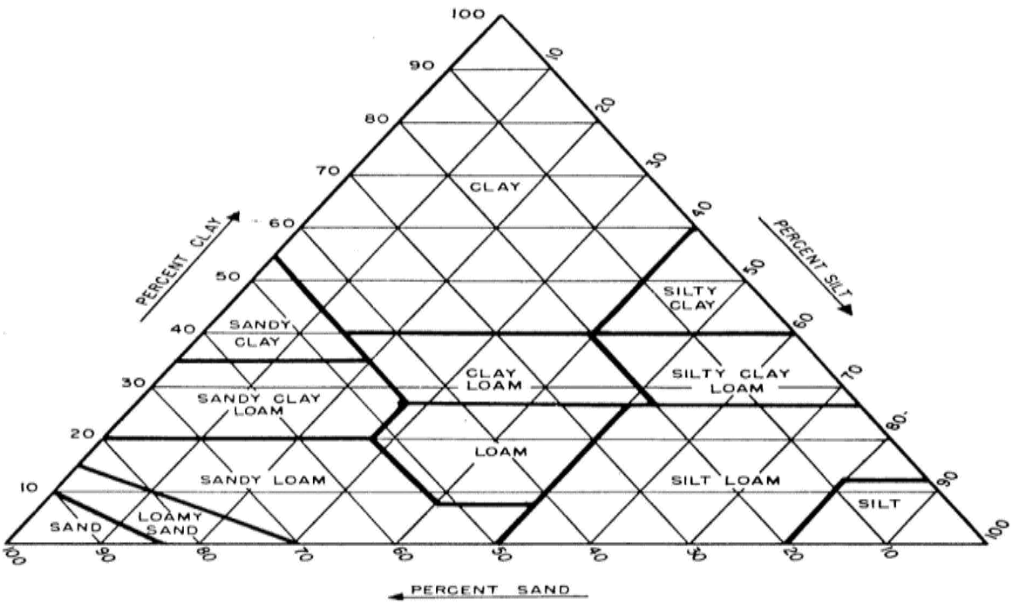

Fig.3: Textural triangle

An EC meter was used to calculate the electrical conductivity of a 1:2.5 ratio extract (Okalebo, 2002). The soil reaction (pH) was determined through potentiometric methods in water and 1N KCl at a 1:2.5 ratio (soil: water and KCl) (Okalebo, 2002). Total exchangeable acidity was determined by 1M KCl extraction solution and the soil extract titrated with sodium hydroxide. A second titration with 1M HCl after addition of sodium fluoride was used to obtain the exchangeable aluminum ((NSS, 1990). Aluminum saturation as a measure of toxicity was calculated by dividing exchangeable aluminum by adding interchangeable bases and interchangeable aluminum.

The organic carbon was measured using the Walkley and Black wet oxidation process (Nelson, D. W., & Sommers, L. E, 1996), and organic matter was detected by multiplying organic carbon by 1.724. (Duursma and Dawson, 1981). The extracting, Bray II solution was used to extract available phosphorus from the soil. The extracted phosphorus is calorimetrically determined using the ammonium molybdate reaction and the formation of molybdate blue color.

In a spectrophotometer, the compound's absorbance is assessed at 882nm and is proportionate to the amount of phosphorus derived from the soil (Okalebo, 2002).

The extraction of soil bases was determined using 1M NH_4OAc (ammonium acetate) and the absorbed NH_4^+ displaced by K^+ using 1M KCl (Thomas, G. W., & Hargrove, W. L, 1984). The Atomic Absorption Spectrophotometer was being used to test the bases $Ca^{2+,}$ $Mg^{2+,}$ K^+, and Na^+ displaced by NH_4^+ (Thomas, 1982). The ECEC was computed as the sum of four exchangeable bases (Ca^{2+}, $Mg^{2+,}$ Na^+, and K^+) plus exchangeable acidity (Al^{3+} and H^+) for a given soil sample.

III. DATA ANALYSIS

Genstat software was used to test differences between treatments in the Migina catchment area. Least significance was measured to determine a significant difference between treatments for each measured parameter and differences were declared significant at α: 0.05 levels. Excel software for data entry, calculations and management.

IV. RESULTS PRESENTATION ON ANALYZED PARAMETERS

Tables of results presentation and interpretation

pH **(Water),** pH**(KCl) in different land management practices**

This section presents the results obtained in physicochemical properties and statistical soil sample analysis of Migina Catchment at Akaboti cell, Kansi Sector, Gisagara District in Southern Province of Rwanda. Those results are presented in the form of figures and tables for facilitating their interpretation. The soil nutrients and chemical parameters that assed, are soil pH (H_2O), pH (KCl), Available Nitrogen (N-NH_4^+ and N-NO_3^-), Available Phosphorus, exchangeable basis (K, Ca, Na, Mg and base saturation), pH (Al^{2+},H^+) and organic carbon, we was analyzing also soil physical properties like moisture content, bulk density, electrical conductivity , particle density and soil texture all of those physicochemical

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properties analyzed for observing the parameters improving soil fertility under different land management practices in Migina catchment.

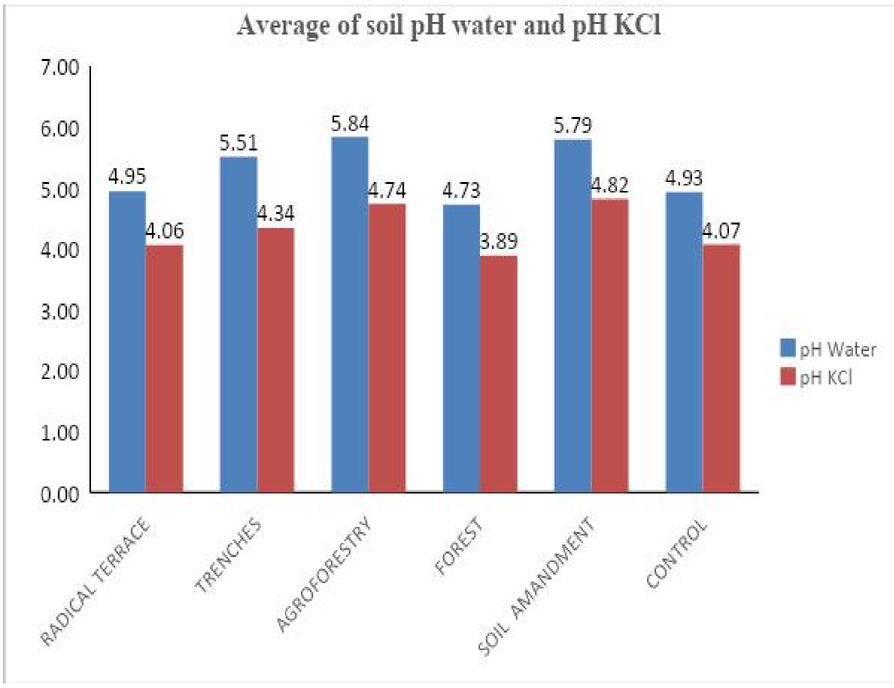

Fig.4: pH Water, pHKCl in different land management practice in Migina catchment

Table I: The results of pH, *electrical conductivity, organic carbon, mineral nitrogen, (N-NH4-N-NO3), available phosphorus*

							Mineral Nitrogen		
Land Management Practice	Soil Sample Stream	$P^{H}H_2O$	$P^{H}{}_{KCl}$	EC (dS/m)	% OC	% OM	N-NH_4 ppm	N-NO_3^- ppm	ppm (Av. P)
Radical terrace	**Upper**	4.98	4.08	0.080	1.53	2.63	2.554	6.89	9.24
	Middle	5.14	4.18	0.076	3.33	5.73	3.359	18.61	10.21
	Bottom	4.73	3.93	0.145	1.71	2.94	3.019	4.36	8.55
Trenches	**Upper**	5.46	4.27	0.138	2.61	4.49	4.104	18.89	17.10
	Middle	5.29	4.17	0.087	2.88	4.96	4.852	11.04	9.49
	Bottom	5.79	4.59	0.366	3.24	5.58	3.574	16.18	12.11
Agroforestry	**Upper**	6.29	5.32	0.188	4.04	6.97	6.315	24.00	16.79
	Middle	5.45	4.3	0.112	3.77	6.51	5.658	18.75	14.78
	Bottom	5.79	4.61	0.390	3.24	5.58	4.466	28.00	12.58
Forest	**Upper**	4.93	3.9	0.102	2.61	4.49	2.982	9.64	10.02
	Middle	4.49	3.91	0.098	2.88	4.96	3.383	18.57	9.98
	Bottom	4.77	3.85	0.129	3.59	6.20	5.304	12.46	14.75
Soil amendment	**Upper**	6.34	5.37	0.141	3.33	5.73	5.727	17.75	14.65
	Middle	5.94	4.96	0.105	3.41	5.89	4.554	20.82	11.99
	Bottom	5.11	4.13	0.155	2.70	4.65	7.239	19.54	12.40
Control	**Upper**	4.69	3.95	0.098	2.34	4.03	3.322	13.39	9.12

	Middle	4.83	4.03	0.080	2.88	4.96	3.767	12.82	9.17
	Bottom	5.27	4.24	0.198	3.95	6.82	3.063	14.29	9.42

The ANOVA table shows that there is a highly significant difference between pH values measured in samples collected from different treatments. The values presented in the figure above are pH water and pH KCl of different land management in Migina Catchment, the pH water and pH KCl of the studied area varies slightly along a topo sequence in general, (Table 1).

The figure shows that P^H water and pH KCl of agroforestry, trenches and soil amendment practices are greater than the P^H of radical terrace and forest management practices. Especially for agro forestry pH is higher than the other land management practices (Figure1).

Generally, the pH of this area is acidic in nature (Table 1). The soils irrespective of the physiographic position along the topography sequence were varying from strongly to slightly acidic with the pH (H_2O) values of 4.73 – 5.14 for radical terraced land; 5.79 – 5.29 for trenches; 6.29 – 5.79 for agroforestry; 4.93 – 4.49 for forest and 5.27 – 4.69 for control (Uwingabire, 2016). The pH in amended land increased with altitude with the values of 6.34, 5.94 and 5.11 for the upper, middle and bottom land respectively; there are no trends of pH decreasing or increasing except in soil amendment practice where pH is decreasing downward.

Electrical Conductivity in different land management practice

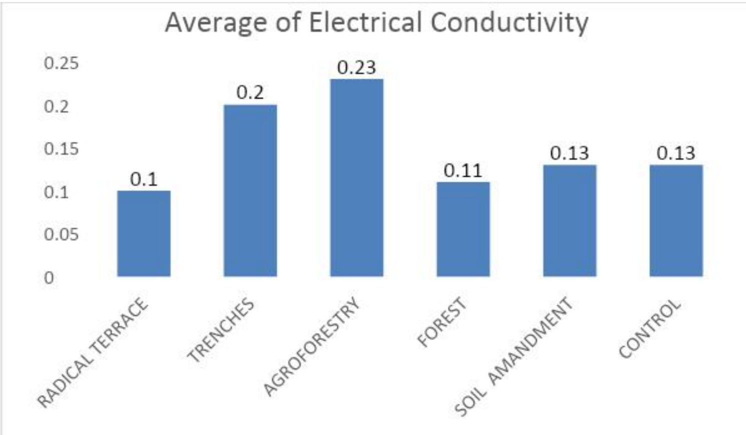

Fig.5: Electrical Conductivity in different land management practice

The ANOVA table shows a highly significant difference between land management ($P<0.01$). The value presented in the figure above is Electrical conductivity of different land management in Migina Catchment, the Electrical conductivity of our studied area varies slightly along a topo sequence in general, (Table 1). According to (E.S. Marx, J. Hart, 1999), The figure shows that the Electrical conductivity is low for all treatments means there is not any salinity effect in my study area and specifically electrical conductivity of agro forestry land management practice is higher compared to the other land management practices while in radical terrace its electrical conductivity is smaller than the other land management practice in our study area (Figure 2).

The Electrical Conductivity in this study area is low in general (Table 1.). Without based on topo sequence electrical conductivity variation, normally were varying as this follow, the electrical conductivity values of 0.076 – 0.146 ds/m for radical terraced land; 0.087 – 0.366 ds/m for trenches; 0.112 – 0.390 ds/m for agroforestry; 0.98 – 0.102 ds/m for forest; 0.15-0.141ds/m for amended land and 0.080 – 0.198 ds/m for control. There are no trends of electrical conductivity decreasing or increasing in topo sequence except in radical terrace practice where electrical conductivity decreases downward.

Carbon and organic matter Percentage in different land management practice

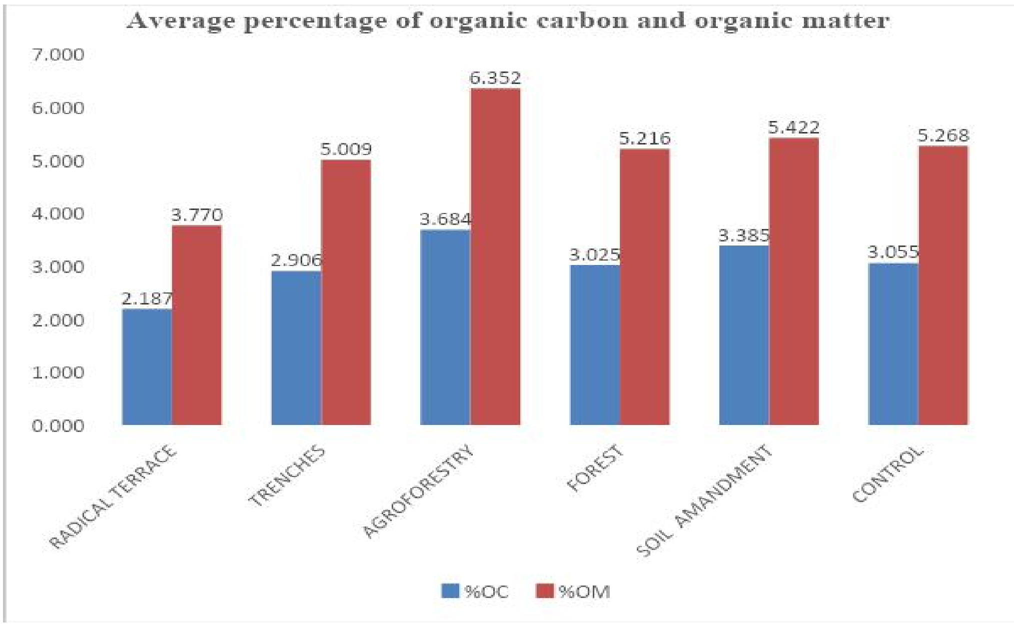

Fig.6: Percentage organic Matter and Carbon Percentage in different land management practice

The ANOVA table shows a significant difference between land management ($P < 0.02$).

The values presented in the figure above are organic carbon and percentage of organic matter in different land management practices in the Migina catchment area. In this different land management practice organic carbon varies slightly along a topo sequence in general, (Table 1).

The figure shows that the agroforestry practice contains higher organic matter and organic carbon than other land management practices while radical terrace has lower organic matter and carbon percentage compared to the other selected land management in this study area (Figure 3). According to Kileo (2000) and EUROCONSULT (1989), generally the organic carbon and organic matter percentage of the study area varies from medium to very high (Table 1.).

The percentage of soil carbon irrespective of the physiographic position along the topography sequence were varying from Medium to high with the % C values from 1.53 – 3.33 for radical terraced land; 2.61– 3.24 for trenches; 3.24 – 4.04 for agroforestry; 2.61 – 3.59 for forest; 2.70-3.33 for amended soil and 2.34 – 3.95 for control as observed from the laboratory analysis.

Soil organic carbon varies from the upper, middle and bottom land respectively There is a specific trend of % OC in treatment as it is increasing downward except in soil amendment practice and in radical terraces where there is no specific trend of % OC variation, and in Trenches increase downward.

Ammonium (NH_4^+) of different land management practice in Migina Catchment

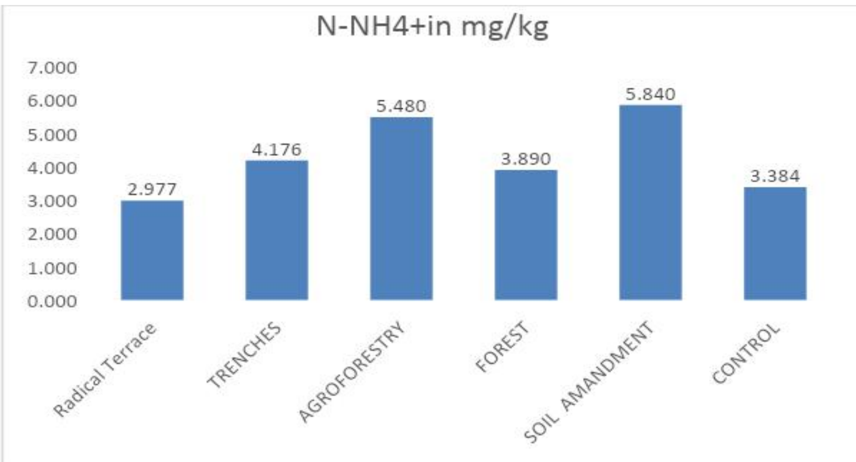

Fig.7: Ammonium ($NH4^+$) percentage in different land management practice

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The ANOVA table shows that there is no significant difference between land management practices (P < 0.042). The values presented in the figure above are Ammonium (NH_4^+) concentration measured between different land management practices in Migina Catchment, Ammonium (NH_4^+) concentration of the studied area varies slightly along a topo sequence in general, (Table 1). The figure shows that Ammonium (NH_4^+) of amended soil are greater than the Ammonium (NH_4^+) of other practices in this area while radical terrace has the smallest Ammonium (NH_4^+) compared to the other land management in Migina catchment (Figure 4). The Ammonium (NH_4^+) of the study area is generally enough (Table 1) as the effective value in soil crop production is from 2-10 ppm (E.S. Marx, J. Hart, 1999). The value of ammonium is presented in (Table 1).

According (Murphy, B, 2014), the upper, middle and lower slopes showed medium to high levels of nitrate ranging from of 2.554 – 3.353 ppm for radical terraced land; 3.574 – 4.852 ppm for trenches; 4.466 – 6.315ppm for agroforestry; 2.982 – 5.304 ppm for forest, 4.554 – 7.239 ppm for amended soil and 3.063-3.767 ppm for control. Referring to topo sequence there are no specific trends of Ammonium (NH_4^+) variation except in forest land management practice where Ammonium (NH_4^+) is increasing downward (Table1).

Nitrate (NO_3^-) of different land management practice in Migina Catchment

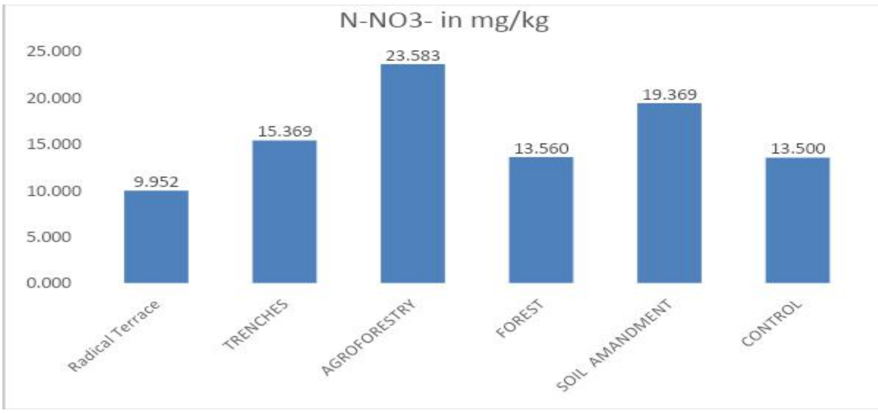

Fig.8: Nitrate (NO_3^-) percentage in different land management practice

The ANOVA table shows that there is a significant different between land management (P<0.006). The value presented in the figure above is Nitrate (NO_3^-) of different land management in Migina Catchment, Nitrate (NO_3^-) of the studied area varies slightly along a topo sequence in general, (Table 1). The figure shows that Nitrate (NO_3^-) of Agroforestry are greater than the Nitrate (NO_3-) of other practices in this area while radical terrace has the smallest Nitrate (NO_3^-) compared to the other land management in Migina catchment (Figure 5).

Generally, the Nitrate (NO_3^-) of the study area is high (table 1.). The value of Nitrate is presented in (Table 1).

According to (Murphy and Hazalton, 2007), the upper, middle and lower slopes showed medium to high levels of nitrate ranging from of 4.36 – 18.61ppm for radical terraced land; 11.04 – 18.89 ppm for trenches; 18.75 – 28 ppm for agroforestry; 9.64 – 18.57 ppm for forest,17.75 – 20.85 ppm for amended soil and 12.82-14.29 ppm for control. Referring to topo sequence, there are no specific trends of Nitrate (NO_3^-) variation (Table1).

Available phosphorus in different land management practice

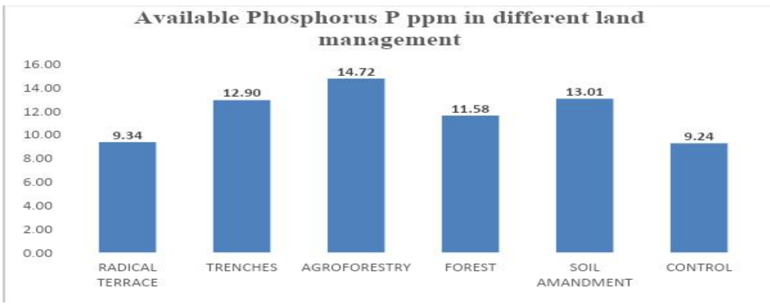

Fig.9: Available phosphorus percentage under different land management practice

The ANOVA table shows a significant difference between land management (P<0.02).

The available phosphorus P varies from 9.24 ppm to 14.47 ppm based on the average available phosphorus of different selected land management in Migina catchment. Generally, all land management Av. P varies in medium but are different from their topo sequence values. According to EUROCONSULT (1989), all practices of our study area classified in mediums differ in values of phosphorus availability in their treatment, where agro forestry, soil amendment, trenches and forest have great value respectively compared to the radical terrace and control.

The most competitive to soil available phosphorus is agroforestry and control is less compared to the other treatments (Figure 6). The soil phosphorus is classified as medium according to (ILACO, 1993; Landon, 1991; Baize, 1993; Msanya*et al.*, 2001). But referring to the topo sequence there significant variation of their availability as this follow for radical terrace varies from 8.55-10.21 ppm, for trenches is 9.24-17.10 ppm, for is Agroforestry 12.58-16.79 ppm, for forest is 9.98-10.02 ppm, for soil amendment is 11.99-14.75ppm and Control is varies from 9.42-9.12 ppm, and there is no specific trends on treatment topo sequence except at control where values varies by increasing downward and in agro forestry varies by decreasing down ward (Table 1).

Exchangeable Bases, Exchangeable potassium

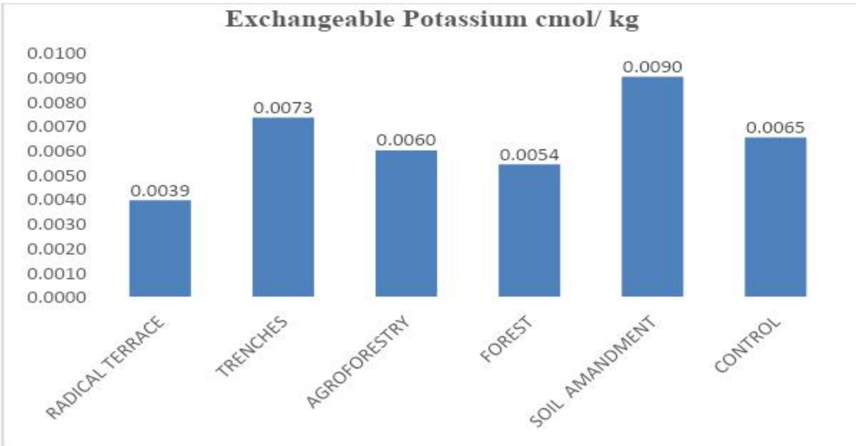

Fig.10: Potassium (K) of different land management practices in Migina Catchment,

The ANOVA table shows a significance between different land management (P < 0.04). The value presented in the figure above is Potassium (K) of different land management in Migina Catchment, Potassium (K) of the studied area varies slightly along a topo sequence in general, (Table 1). The figure shows that Potassium (K) of Agroforestry are greater than the Potassium (K) of other practices in this area while radical terrace has the smallest Potassium (K) compared to the other land management in Migina catchment (Figure 7).

Generally, the Potassium (K) of the study area is very low (table 2). The soils vary based on their physiographic place along the topo sequence as this follow values of 0.0028 – 0.0056 cmol/kg for radical terraced land; 0.0035 – 0.0144 cmol/kg for trenches; 0.0036 – 0.0145 cmol/kg for agroforestry; 0.0043 – 0.0066 cmol/kg for forest, 0.0043 – 0.0142 cmol/kg for amended soil and 0.0052-0.0084 cmol/kg for control (ILACO,1993; Landon, 1991; Baize, 1993; Msanya*et al.*, 2001). Referring to topo sequence there is a trends of Potassium (K) in radical terrace, trenches increase downward also in forest and control (undisturbed land) is decreasing downward except in Agroforestry and soil amendment land management practices where there is no trends of Potassium (K) variation (Table 2).

Exchangeable Magnesium

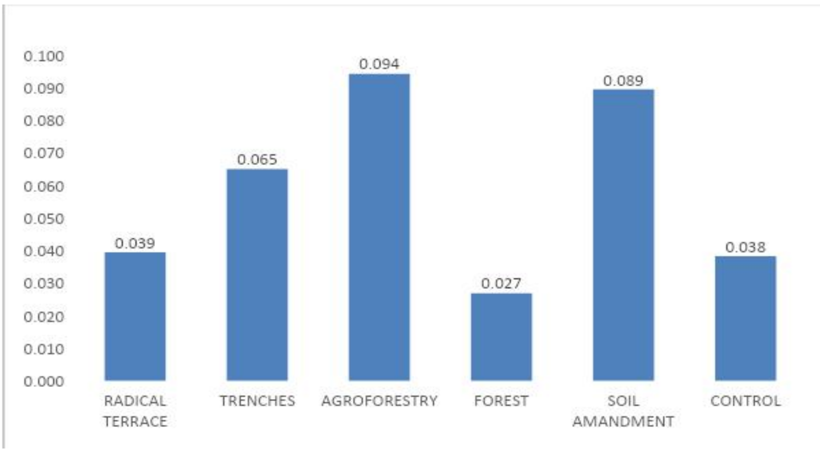

Fig.11: Exchangeable Magnesium under different land management practices

The ANOVA table shows that there is a less significant difference between land management (P<0.042). The value presented in the figure above is Magnesium (Mg) of different land management in Migina Catchment, Magnesium (Mg) of the studied area varies slightly along a topo sequence in general, (Table 1). The figure shows that Magnesium (Mg) of Agroforestry is greater than the Magnesium (Mg) of other practices in this area while forest has smallest Magnesium (Mg) compared to the other land management in Migina catchment (Figure 8). The Magnesium (Mg) of the study area is in general very low to low (Table 2). The value of Magnesium (Mg) is presented in (Table 1). According (Murphy and Hazalton, 2007), the upper, middle and lower slopes showed the levels of Magnesium (Mg) ranging from 0.03 – 0.44cmol/kg for radical terraced land; 0.05 – 0.9 cmol/kg for trenches; 0.08 – 0.11 cmol/kg for agroforestry; 0.02 – 0.09 cmol/kg for forest, 0.03 – 0.11 cmol/kg for amended soil and 0.03-0.06 cmol /kg for control (ILACO, 1993; Landon, 1991; Baize, 1993; Msanya*et al.*, 2001). Referring to the topo sequence there are no trends of Magnesium (Mg) values (Table 2).

Table 2: The results of exchangeable bases and acidity Calcium (Ca), Magnesium (Mg), Potassium (K), Sodium (Na), ECEC and Base Saturation

Land mgt practice	Soil Sample Stream	Cmol/kg (Ca)	Cmol/kg (Mg)	Cmol/kg (K)	Cmol/kg Na	(TEB)CEC (cmol(+)/kg	ECEC Cmol(+) /kg)	% BS
Radical Terrace	Upper	0.1	0.04	0.00287	0.021	0.16	4	11.34
	Middle	0.14	0.04	0.00328	0.027	0.21	2.29	9.3
	Bottom	0.13	0.03	0.00564	0.016	0.18	1.3	14.12
Trenches	Upper	0.14	0.06	0.00354	0.012	0.21	1.81	11.81
	Middle	0.18	0.05	0.00395	0.062	0.29	1.01	28.83
	Bottom	0.24	0.09	0.01446	0.106	0.45	0.93	48.27
Agroforestry	Upper	0.14	0.11	0.01421	0.058	0.32	0.4	79.82
	Middle	0.13	0.08	0.00303	0.101	0.31	0.95	32.65
	Bottom	0.2	0.09	0.01456	0.117	0.42	4.02	10.48
Forest	Upper	0.12	0.03	0.00667	0.019	0.18	3.22	5.46
	Middle	0.13	0.02	0.00518	0.03	0.19	2.91	6.43
	Bottom	0.16	0.03	0.00436	0.017	0.21	1.01	20.96
Soil amendment	Upper	0.14	0.11	0.01421	0.058	0.32	0.4	79.82

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	Middle	0.14	0.1	0.00692	0.238	0.48	1.84	25.98
	Bottom	0.15	0.06	0.00585	0.091	0.31	0.95	32.52
Control	Upper	0.13	0.03	0.00841	0.051	0.22	3.1	7.06
	Middle	0.16	0.03	0.0059	0.075	0.27	3.31	8.02
	Bottom	0.18	0.05	0.00523	0.021	0.26	1.38	18.7

Exchangeable Calcium

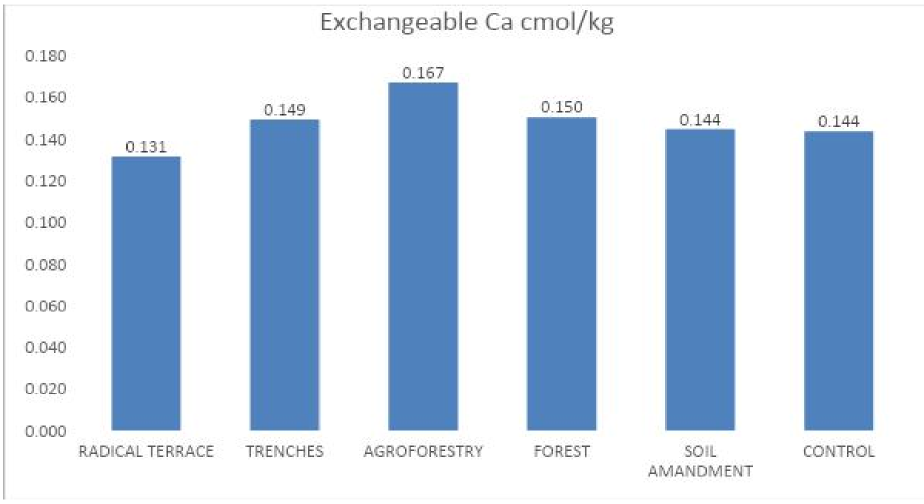

Fig.12: Exchangeable Calcium under different land management practices

The ANOVA table shows less significance between land management (P<0.046).

The values presented in the figure above is Calcium (Ca) of different land management in Migina Catchment, Calcium (Ca) of the studied area varies slightly along a topo sequence in general, (Table 2). The figure shows that Calcium (Ca) of Agroforestry are greater than the Calcium (Ca) of other practices in this area while radical terrace has smallest Calcium (Ca) compared to the other land management in Migina catchment (Figure 9). Generally, the Calcium (Ca) of the study area is low (table 2). The soils irrespective of the physiographic position along the topo sequence were varying as this follow values of 0.10 – 0.14 cmol/kg for radical terraced land; 0.14 – 0.24 cmol/kg for trenches; 0.13 – 0.20 cmol/kg for agroforestry; 0.12 – 0.16 cmol/kg for forest, 0.14 – 0.16 cmol/kg for amended soil and 0.11-0.14 cmol/kg for control (ILACO, 1993; Landon, 1991; Baize, 1993; Msanya*et al.*, 2001). Referring to topo sequence there are no trends of Calcium (Ca) except in trenches and control (undisturbed land) land management practices where Calcium (Ca) is increased downward (Table 2).

Exchangeable sodium

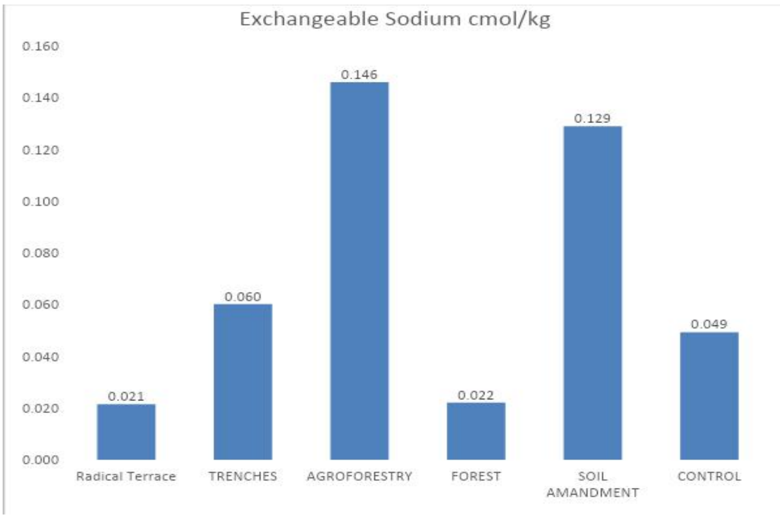

Fig.13: Exchangeable sodium under different land management practices

The ANOVA table shows that there is a significant difference between land management ($P < 0.002$). The value presented in the figure above is Sodium (Na) of different land management in Migina catchment, Sodium (Na) of the studied area varies slightly along a topo sequence in general, (Table 2). The figure shows that the Sodium (Na) of Agroforestry is greater than other practices in this area while radical terrace and forested land have smallest Sodium (Na) compared to the other land management in Migina catchment (Figure10).

Generally, the Sodium (Na) of the place of study is very low (Table 2). The value of Sodium (Na) is presented in (Table 1). According (Hazelton, P., & Murphy, B, 2007), the upper, middle and lower slopes showed the levels of Sodium (Na) ranging from 0.016 – 0.021 cmol/kg for radical terraced land; 0.012 – 0.106 cmol/kg for trenches; 0.101 – 0.230 cmol/kg for agroforestry; 0.017 – 0.030 cmol/kg for forest, 0.058 – 0.238 cmol/kg for amended soil and 0.021-0.075 cmol/kg for control (ILACO, 1993; Landon, 1991; Baize, 1993; Msanya*et al.*, 2001). Referring to topo sequence there are no trends of Sodium (Na) except in trenches management practice where Sodium (Na) is increasing downward (Table 2).

ECEC (Effective Cation Exchange Capacity)

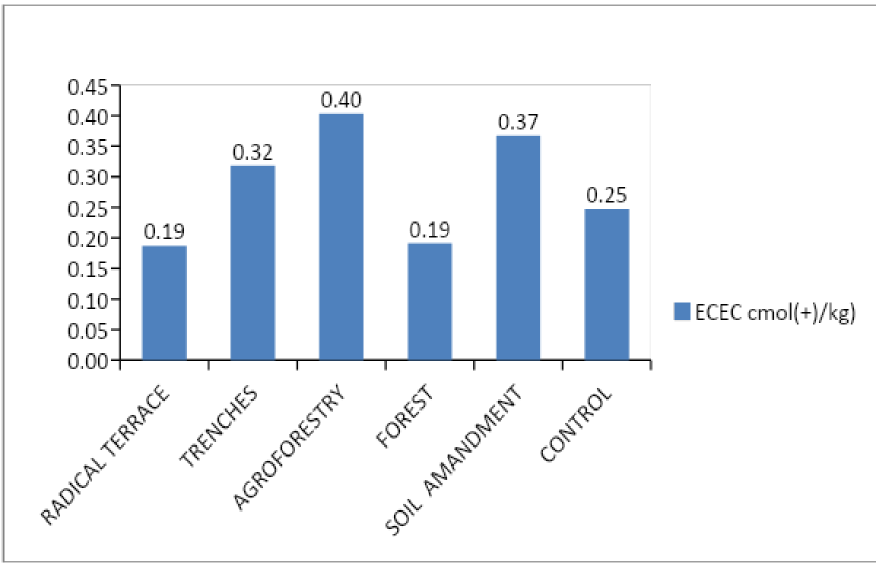

Fig.14: Effective Cation Exchange Capacity (ECEC) under different land management practices in Migina catchment

The ANOVA table shows that there is a less significant difference in different land management ($P < 0.046$). The value presented in the figure above is Effective Effect of Cation Exchange capacity (ECEC) of different land management in Migina Catchment, Effective Cation Exchange Capacity of the studied area varies slightly along a topo sequence in general, (Table 2). The figure shows that the Effective Cation Exchange Capacity of

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Agroforestry is more than other practices in this area while Forestry and radical Terrace have the smallest Effective Cation Exchange Capacity compared to the other land management in Migina catchment (Figure11). Generally, the Effective Cation Exchange Capacity of the study area is low (table 2.). The soils irrespective of the physiographic position along the topo sequence were varying as this follow values of 0.16 – 0.21 cmol/kg for radical terraced land; 0.21 – 0.45 cmol/kg for trenches; 0.31 – 0.48 cmol/kg for agroforestry; 0.18 – 0.21 cmol/kg for forest, 0.31 – 0.48 cmol/kg for amended soil and 0.22-0.27 cmol/kg for control (ILACO, 1993; Landon, 1991; Baize, 1993; Msanya*et al.*, 2001). Referring to topo sequence there are no trends of Effective Cation Exchangeable Capacity (ECEC) except in trenches land management practice where Effective Cation Exchangeable Capacity (ECEC) is increased downward (Table 2).

Base Saturation

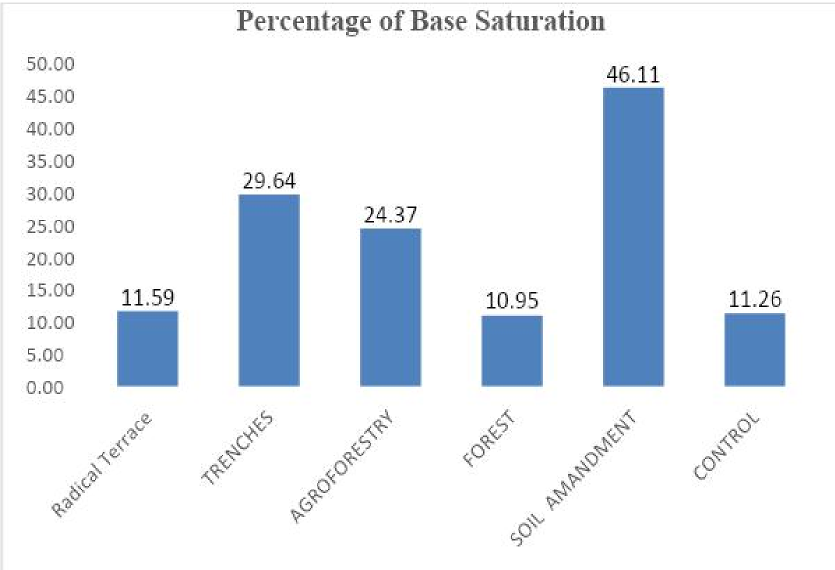

Fig.15: Percentage of base saturation under different land management in Migina catchment

The ANOVA table shows there is a less significant difference in land management ($P < 0.04$).

The value presented in the figure above is percentage Base Saturation of different land management in Migina catchment, Base Saturation of the studied area varies slightly along a topo sequence in general, (Table 2).

The figure shows that the Base Saturation of Agroforestry is greater than other practices in this area while radical terrace and forested land have smallest Base Saturation compared to the other land management in Migina catchment (figure12). The Base Saturation of the study area is in general, low (table 2). The soils irrespective of the physiographic position along the topo sequence were varying as this follow values of 9.30 – 14.12 % for radical terraced land; 11.81 – 48.27 % for trenches; 10.48 – 29.99 % for agroforestry; 5.46 – 20.96 % for forest, 25.98 – 79.82 % for amended soil and 7.06-18.70 % for control (ILACO, 1993; Landon, 1991; Baize, 1993; Msanya*et al.*, 2001). Referring to topo sequence there are no trends of Base Saturation amended, terraced and agro forested land but in trenches, forest and control land management practices, base saturation is increasing downward (Table 2).

Table 3: The results of exchangeable acidity Aluminium (Al^{3+}), hydrogen (H^{+}), Aluminum Saturation and Total Exchangeable Acidity

Land Management Practice	Sample Stream	TEA (meq/100g)	Al^{3+} (meq/100g)	H^{+} (me/100)	Al. Saturation
Radical Terrace	Upper	1.28	1.12	2.4	0.887
	Middle	2.08	0.96	1.12	0.907
	Bottom	1.12	1.36	2.48	0.859
Trenches	Upper	1.6	0.88	0.72	0.882

	Middle	0.72	0.8	1.52	0.712
	Bottom	0.48	0	0.48	0.517
Agroforestry	Upper	1.12	1.12	0	0.7
	Middle	0.64	0.16	0.8	0.673
	Bottom	3.6	3.2	0.4	0.895
Forest	Upper	3.04	0.16	3.2	0.945
	Middle	2.72	0.48	3.2	0.936
	Bottom	0.8	2.32	3.12	0.79
Soil Amendment	Upper	0.08	0.08	0	0.202
	Middle	1.36	0.48	1.84	0.74
	Bottom	0.64	0.48	0.16	0.675
Control	Upper	2.88	0.64	3.52	0.929
	Middle	3.04	0.16	2.88	0.92
	Bottom	1.12	1.44	2.56	0.813

Exchangeable Acidity

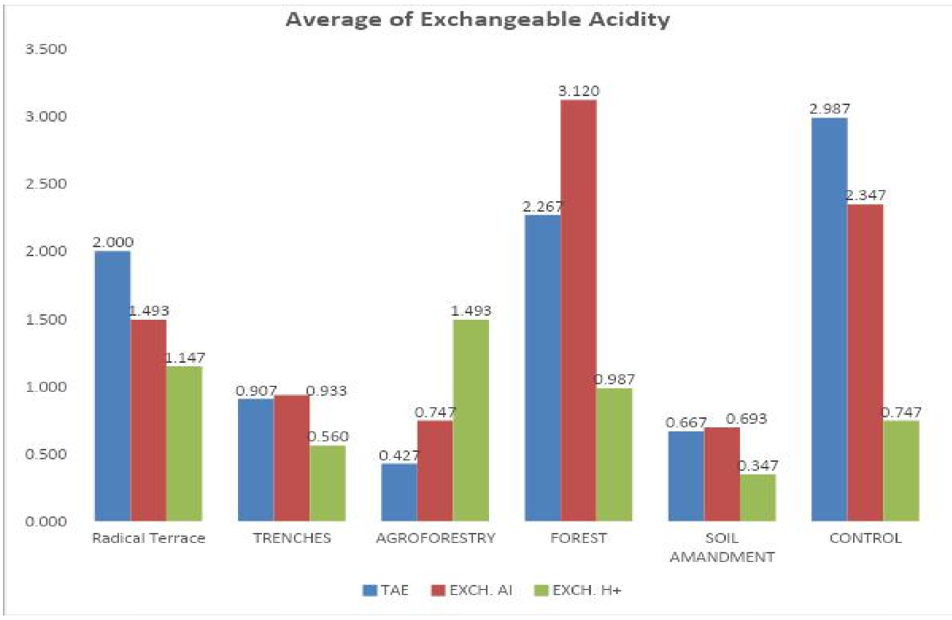

Fig.16: Exchangeable acidity of different land management practices in Migina Catchment

The ANOVA table shows that there is a significant difference in land management ($P < 0.006$), ($P < 0.04$) for Aluminum and Hydrogen respectively. The value presented in the figure above is Total Exchangeable Acidity, exchangeable aluminum and of different land management in Migina Catchment, the exchangeable acidity of the studied area varies slightly along a topo sequence in general, (Table 2). The figure shows that the acidity is very dominant in control, forest and radical terrace compared to the other land management in Migina catchment, the exchangeable Aluminum is more than exchangeable hydrogen in the study area (Figure13). Generally, the Total Exchangeable Acidity of the study area is high (Table 3.). The soils irrespective of the physiographic position along the topo sequence were varying as this follow respectively exchangeable aluminum and hydrogen values are 1.12 – 2.08,0.96-1.36 meq /100g for radical terraced land; 0.48 – 1.16, 0-1.12meq /100g for trenches; 0.48 – 1.12 ,0.16-3.2meq /100g for agroforestry; 0.8 – 3.04, 0.16 – 2. 32 meq /100g

for forest, 0.008 – 1.36, 0.8-0.48 meq /100g for amended soil and 1.12-2.88, 0.16-1.44 meq /100g for control (ILACO, 1993; Landon, 1991; Baize, 1993; Msanya*et al.*, 2001). Referring to topo sequence there are no trends of Exchangeable acidity except in control or undisturbed land where Exchangeable acidity is decreasing downward (Table1).

Soil texture under different land management

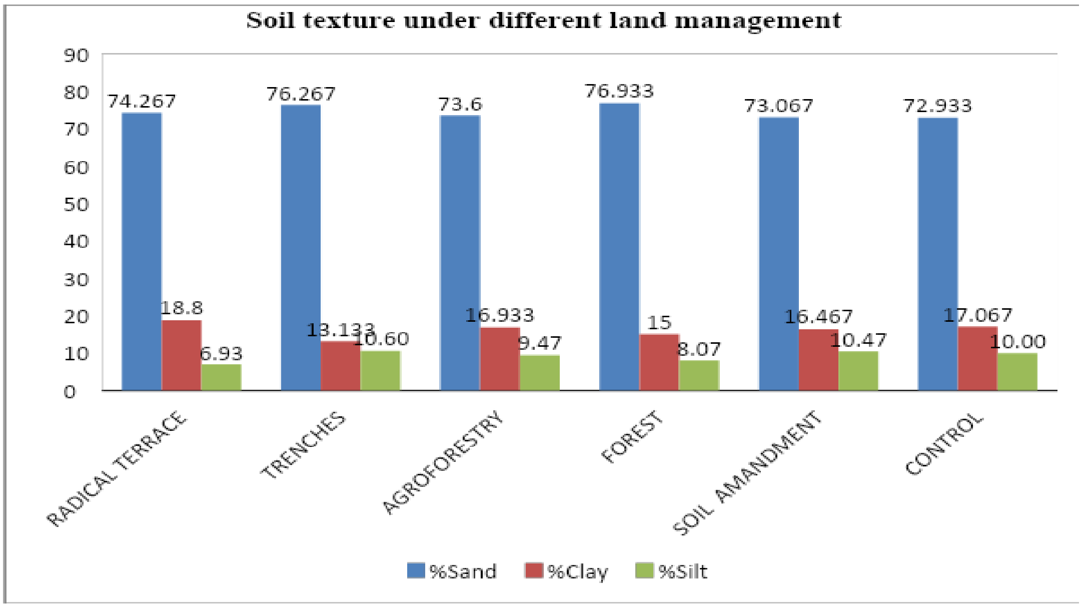

Fig.17: Soil Texture under different land management in Migina catchment

The study site is dominated by sandy loam (Table 4) except bottom of terraced land and upper land of agroforestry land use. All samples had a higher content of sand (79.6-69.6 %) than that of silt and clay content. The result (Table 3) of the soil texture showed that percent sand decreased down the slope in terraced and controlled lands ranging from 75.6 and 73.6 % and 75.6 and 71.6 % respectively (Figure 14).

Percentage of porosity and moisture content under different land management

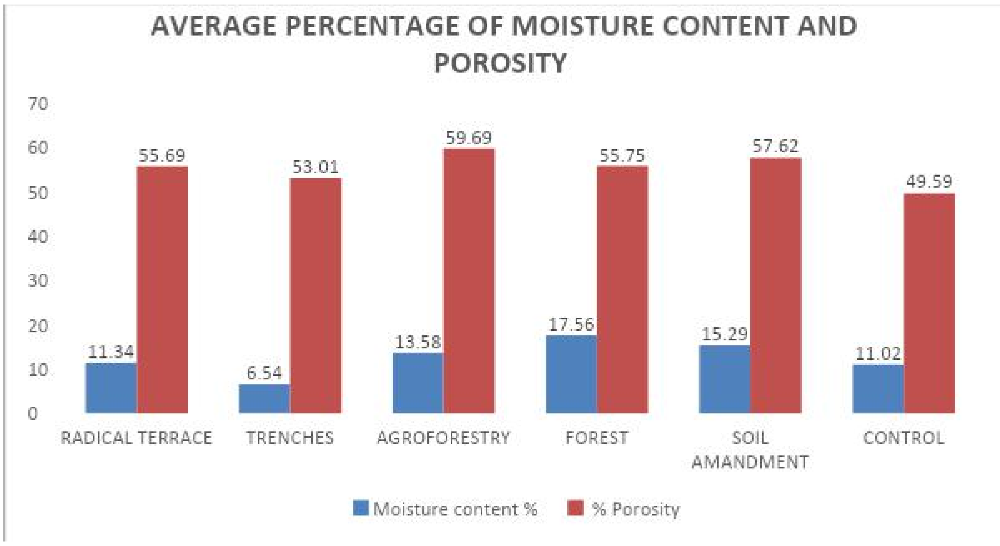

Fig.18: Percentage of porosity and moisture content under different land management

The ANOVA table shows a highly significant difference management on moisture content (P < 0.001). The values of total porosity ranged between 50.2 and 52.08 in terraced land; 47.2 and 58.16 in trenches; 53.8 and 63.87 % in agroforestry; 53.08 and 53.8 % in forestry; 56.39 and 58.9 % in amended soil and 45.9 to 51.84 in the control 0r undisturbed land (Table 4). There is no trend of increasing or decreasing slope position in terraced, agroforestry,

amended and controlled land uses. The increases with slope have been found in forest land whereas the increase with slope was in the trenched farm. High porosity was found in agroforestry land use (Figure 15), since agroforestry systems increase soil organic matter hence high porosity.

Percentage of moisture content

The values presented in the previous figure shows that in general moisture content varies in range of 6.54 % to 17.56 % in our study area where forest land has the highest moisture content which is (17.56 %) and the smallest one is trenched land with 6.54% (Figure 15). The values of moisture content ranged between 9.93 and 16.18 % in terraced land; 3.09 and 10.09 % in trenches; 10.23 and 17.276 % in agroforestry; 15.27 and 19.37 % in forestry; 13.237 and 17.032 % in amended soil and 7.23 to 13.077 % in the control (undisturbed land) (Table 3). There are no specific trends of moisture content values variation in our study area except in agroforestry and forestry where they increase down ward. The ANOVA Table shows a significant difference between land management (P< 0.01) on bulk density. The values presented on figures are Bulk density and particle size distribution and the figure shows that the bulk density is low in terraced, trenches, agroforestry, forestry, amended soil and in control ranging from 0.96 to 1.44 g/cm^3 this is a good range for plant growth. The values presented on the previous figure shows that agro forestry has small value of bulk density (1.07 g/cm^3) compared to the other land management practices while control (undisturbed soil) has a highest value of bulk density (1.34 g/cm^3) but all of them has favorable bulk density for root growth penetration and crop growth in general (Figure 16).

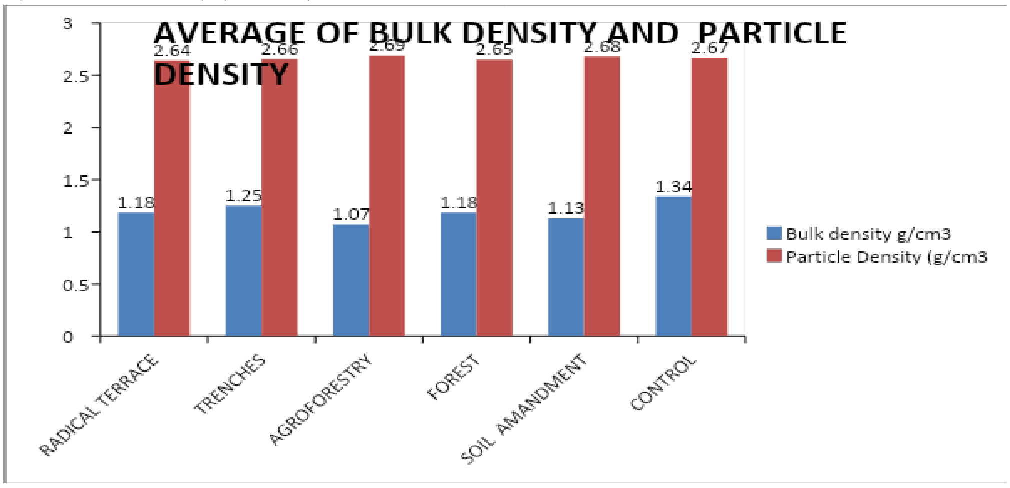

Fig.19: *Bulk Density and particle density under different land management in Migina Catchment.*

Bulk density and particle density under different land management practices in Migina Catchment

Table 4: The results on Soil texture, Moisture content, Bulk Density, Particle Density and Porosity

		Particle size distribution							
Land management practices	**Sample Stream**	**% Sand**	**% Clay**	**% Silt**	**Textural classes**	**Moisture content %**	**Bulk Density g/cm^3**	**Particle Density g/cm^3**	**% Porosity**
Radical Terrace	Upper	75.6	16.2	8.2	Sandy Loam	9.936	1.276	2.61	52.03
	Middle	73.6	17.8	8.6	Sandy Loam	7.917	1.11	2.65	58.27
	Bottom	73.6	22.4	4	Sandy Clay Loam	16.18	1.15	2.68	56.77
Trenches	Upper	75.6	13.8	10.6	Sandy Loam	6.434	1.404	2.52	47.22
	Middle	77.6	14.6	7.8	Sandy Loam	3.09	1.233	2.7	53.65
	Bottom	75.6	11	13.4	Sandy Loam	10.09	1.113	2.62	58.16

Agroforestry	Upper	69.6	20.8	9.6	Sand Clay Loam	10.213	1.027	2.71	61.39
	Middle	73.6	15.2	11.2	Sandy Loam	13.241	1.229	2.68	53.8
	Bottom	77.6	14.8	7.6	Sandy Loam	17.276	0.961	2.67	63.87
Forest	Upper	75.6	17.4	7	Sandy Loam	19.3713	1.04	2.72	60.9
	Middle	79.6	10.8	9.6	Sandy Loam	18.031	1.243	2.62	53.27
	Bottom	75.6	16.8	7.6	Sandy Loam	15.2737	1.248	2.61	53.08
Soil Amendment	Upper	75.6	17.4	7	Sandy Loam	19.3713	1.04	2.72	60.9
	Middle	79.6	10.8	9.6	Sandy Loam	18.031	1.243	2.62	53.27
	Bottom	75.6	16.8	7.6	Sandy Loam	15.2737	1.248	2.61	53.08
Control	Upper	75.6	14.4	10	Sandy Loam	7.2309	1.439	2.69	45.9
	Middle	71.6	18.4	10	Sandy Loam	13.077	1.281	2.64	51.84
	Bottom	71.6	18.4	10	Sandy Loam	12.743	1.303	2.67	51.02

V. DISCUSSION

5.1 pH Water, pH KCl of different land management practices

The soil reaction level is an indicator of soil acidity. In our study area, especially in agroforestry and amended soil practices, there is high concentration of population settlement on the top and middle who used to amend their land with organic and household waste fertilizers, the heavy rainfall (1200mm/year) could be to reason for the high pH rate because of the gritty hardness of the soil caused by high weathering, the research region suffers extensive leaching of basic cations. Low pH in the study area is probably induced by acidifying nitrogen fertilizer, nitrate leaching, exclusion of the bases through crop harvests and the farming practices especially in amended soil, trenches, agroforestry and radical terrace (Mackenzie, B., & Erickson, J. D, 2004). Agroforestry systems, the bases deposition above numerous years by growing can influence the arising of pH of soil, the buffering effects of nutrients leaching (Sharma, R., Chauhan, S. K., &Tripathi, A. M, 2016). Particularly in radical terraces the source of their acidity becomes from their poor establishment and poor management of those terraces where in their establishment used to remove top soil which contain all nutrient elements and put them away, the farmers who used to cultivate this radical terrace, they do not use mulching, liming or other pH restoring strategies for increasing soil pH in soil except in middle area where the farmers are tried to use cattle fertilizers. There is low pH also in forest, the leaves and litters increase soil organic carbon in soil after their decomposition but in this process of decomposition release organic acid in soil which decreases soil pH.

The strongly acid reaction amounts propose potential low accessibility of both the macro and micro plant nutrients for being taken by plants. pH values in the soil below 5.5 have the ability to cause toxicity issues. It can also result in the breakdown of aluminum and iron minerals, which precipitate with phosphorus, effectively fixing it and lowering the soil pH (Brady and Weil, 2008). The majority of plants thrive in soils with a pH of 6.5 to 7.5. (Baize, 1993). Thus, soils studied may present limitations to crop growth because of the low P^H values of less than 5.5 which may limit availability of various plant nutrients such as phosphorus and bases (Marschnr, 1995). Application of liming materials may be considered necessary to raise the pH to favorable levels of around pH 6.5 and 7.5. Alternatively, crops that tolerate acidity are recommended for, because plant species and varieties differ in the degree to which they tolerate pH values outside the range, application of more organic fertilizers and application of agroforestry systems are recommended here.

5.2 Electrical Conductivity of different land management practice

Electrical conductivity testing is a consistent way to evaluate how salts are impacting the growth of plants. The EC of soil and water is improved by decomposition and the concentration of salt which is dissolved. Salts arise from the ability of solution to conduct an electrical current, High salinity level is indicated by higher values of EC (Apal, 2014). Therefore, our study area does not face the problem of salinity. Excessive salt in soil may hinder germination of seed. Excessive fertilization and poor water quality used in irrigation are source of salt (Marx, E. S., Hart, J. M., & Stevens, R. G, 1996)

5.3 Percentage of organic carbon and organic matter of different land management practice

The high amount of OC observed may be due to the fallow period. The area under study has been kept as fallow like our control which is not used for tillage activities Johnsons (2002) observed the higher concentration of OM in the surface soil under no-tillage systems this important reason of %OC sufficient in our control. Greater accumulation of surface carbon is resulted by less disruption because the fodder crops roots and the slower decomposition rate of OM might have contributed to the increase of OM in soil with no tillage. It also has a high water holding capacity and penetration rate, which can help to mitigate soil erosion caused by runoff surface water during rainstorms (Njuguna, J.W, 2019).

In agro forestry the high values of OM in topsoil than subsoil may be attributed by decomposition of large quantities of plant residues into the soil every season and high population density in top and middle land. Such good climatic conditions are favorable for vegetation. Low cropping activity and harvesting lead to the losses of nitrogen and carbon (Dowuona*et al*., 2012 and Kebeney*et al*.,2015). And also while soil has low soil P^H lead to the low organic carbon in soil as that low P^H inhibits the microbial activity for decomposing organic matter (Sultana, 2011). While the ground is covered really generate a great potential and generate soil organic carbon and influencing biological activity and favors soil protection, the high concentration of population settlement in agroforestry and soil amendment is one of proposed reason of OC % increasing in this areas where they used to apply more organic fertilizers, agroforestry species and mulching (Sharma et al., 2009).

5.4 General discussion of Nitrate and Ammonium in study area

Nitrate and Ammonium are chemical parameters which show the nitrogen form that are taken up by plan, the level of nitrate and ammonium is affected by rainfall, level of stored water at sowing, time of sampling, depth of taken sample. The high values of nitrate in the study area may be due to fertilizer application containing nitrogen. Ammonium nitrogen concentration values are within the range (2-10 ppm) of agricultural soil (Marx E.S., Hart J., 1999). Ammonium-nitrogen generally does not accumulate in the soil, as soil temperature and moisture condition which is appropriate for the growing of the plant and are ideal for conversation of NH_4-N to NO_3-N. Soil NH4-N level above 10 ppm may take place in cold or extreme soil which is wet, while soil hold fertilizers from a later application, while there is high or low soil pH, and while there is a high soluble salts (measured by electrical conductivity). (D.A. Horneck, D.M. Sullivan, J.S. Owen, and J.M. Hart, 2011). The nitrate level in soil changes widely, basing on the types of soil, rainfall and condition of climate and practices of fertilizing. Any level of nitrate ranging from or more than 25 to 30 ppm is enough to the growth of plants in a vegetable garden (Camberato and Nielsen, 2017).

Due to the leaching and heavy rain the sand soils loses its nitrate, then by denitrification also the coarsely textured soil loses nitrates and this might be the cause of low nitrate in the studied area because the soils have sand presence in its soil texture (Brouder*et al*., 2003). Another reason for high amount is that nitrate accumulates more in the soil because in the period of rain season, the temperature of soil is low and the tension of oxygen is also low referring to the saturation with water and this situation decelerates denitrification (Nielsen, 2017). Agro forestry trees, especially leguminous trees, enrich soil by biological nitrogen fixation, organic matter addition, and nutrient recycling. The fixed nitrogen can provide a symbiotic advantage to the crops that grow alongside it, as well as aid in soil fertility improvement. The amount of nitrogen taken up by the first harvest from legumes or forest trees replanting is stated to be very limited, with a significant portion remaining in the soil organic matter, suggesting a long-term nitrogen advantage rather than an immediate gain. Different tree elements, such as leaves, twigs, berries, and wood, decompose at different speeds, which helps to spread nutrient release over time.

5.5 Available phosphorus of different land management practices

The medium values of P may probably be due to continuous cultivation without replenishment of P from different P fertilizers, for this case the application of chemical fertilizer increase availability of phosphorus probably can be the reason for having high values of available phosphorus in some amended soil. The relatively high values of P found in some topo sequences may be caused by anthropogenic effects including addition of manure, crop residue and inorganic P fertilizers and low potential for phosphorus fixation. Low available phosphorus may be attributed to low soil P^H (<5.8) that could react with iron (Fe) and Aluminum (A_l) to make insoluble Fe and A_l phosphates that are not readily available to be taken by plant (Hodges, 2007, Raymond and Roy, 1990). By binding Al, Fe, and Ca and creating soluble P that may be accessible to plants, raising the amount of organic matter in the soil may help to reduce any P ‘fixation' reactions that may be present. (Hodges, 2007). Then the insufficient soil organic matter in some treatment is another issue of decreasing availability of

phosphorus in some treatment of our study area. The mulching is also in order for reasons which hinder the leaching of nutrient elements and keeping good physical characteristics of soil, this also other issues of great value of AV. P in trenches, amended soil and agroforestry because in the same areas of these practice areas, farmers used to apply mulching. Therefore, by Defoer et al. (2000) this means that very limited amount of phosphorus is available as pH decreases, and unavailability of phosphorus leads to the low productivity of crops and trees as an essential element for crop growth.

5.6 General discussion of exchangeable basis

The values of Exchangeable bases show that it is on Low level, this low level of exchangeable bases is probably due to poor practice of cultivation, soil which is poor and conservation of water and insufficient supply of fertilizer to refill nutrients removed with crops. Another reason could be that the parent material on which soil has developed is poor in bases.

Msanya*et al*. (2001) reported that the desired saturation level of exchangeable Mg is between 10 to 15%. Consequently, for crop processing, the soils of the study areas lack sufficient amounts of exchangeable magnesium, calcium, and potassium. This low exchangeable caution value has direct consequences for cation exchange potential (CEC), soil P^H, and, consequently, plant nutrient imbalances, unavailability, and nutrient induced deficiency.

5.7 Effective cation exchange capacity of different land management practices

The values of ECEC of the soils studied show that it is low; these values are contributed by the kaolinite and sesquioxide or oxidic clays which are dominant clay minerals in highly weathered soils, lacking negative charges. Consequently, they don’t retain adsorbed cations and end up with insufficiency CEC due to the nutrient retention capacity which is low (Landon, 1991).

The land management which has more ECEC values in our study area can be credited to higher content soil organic matter (Tomašić*et al*., 2013). Due to the observation in the field, the low ECEC levels in control or undisturbed land observed could also be attributed to low leaching instead of strong runoff due to high erosion rate as these sites are steeply sloping areas. Erosion causes sediment loss from the upper part (soil truncation) and deposition of new material in the lower part (soil aggradation), this resulted in loss of nutrients in the upper part of the mountains.

The ECEC values indicate possible negative influence on the soil buffering capacity and reduced retention of base cations by the soils studied. Consequently, it doesn’t have the ability to protect soluble cations from leaching out the root zone of plants and helps soils to resist variation in change P^H (Barker *et al*., 2007; Brady and Weil, 2008). The rainfall of our studied land is high; this is another reason for ECEC decreasing because many cations are leaching into the soil (Paul & Rattan, 2014).

5.8 Base Saturation of different land management practices

The values of base saturation of the soils studied are presented in table 3. The findings suggest that there are low base saturation levels in this sample region, which may be due to the pH being very acidic and potentially toxic cations such as aluminum and manganese in the soil (Hodges, 2007). Low levels of bases in most soils are due to improper agricultural methods, poor soil and water management, and an insufficient availability of fertilizer to replenish nutrients removed by crops, among other factors (Ellenkamp, 2004; Jones et al., 2013)., suggesting strong soil productivity for crop development. It also means that there is little to no extensive leaching of bases from the topsoil to the subsoil (Msanya*et al*., 2016).

5.9 Exchangeable Acidity of different land management practices

These results indicate that the acidity of these soils is mostly contributed by exchangeable Al to a large extent and by hydrogen to a moderate extent. Aluminum ions are released from clay lattices at P^H values of about below 5.5 and become exchangeable in the clay complex (Landon, 1991).

5.10 Soil texture under different land management

According to Mc Donald *et al*. (1994), the sand content is very high compared to clay and silt in the study area. The sand nature may probably be attributed by parent material and climate as earlier reported by (Onweremadu et al., 2011; Osujieke et al., 2016).

Soils of high altitude cold desert which have come from rock weathered; they are not mature and have higher amounts of sand gravels and stones in them showing the presence of sand forming minerals in parent material. Sand is a present particle in the hilly soil and they are coming from parent material of sandstones. Clay and silt content have been rated as low. This low value indicates that a soil doesn’t have enough ability for retaining available water for growth of plants due to the unique combination of surface area and sizes of pores (McDonald *et al*.,1994).

5.11 Percentage of porosity and moisture content of different land management practices

The moisture content referring to the water content in brief is an indicator of water present in the soil (ASTM, 2014). Our study is moisture content varies from 6.54 to 17.56%

then according to Bandyopadhyay& Reza (2014), The studied soil result show that there is moderate water retention and referring to Mbaga, Msanya, &Mrema (2017), Tennga et al. (2018) and Uwingabire et al. (2016), the moisture content depends on the soil organic matter, particle size distribution, bulk density and structure of the soil influence the variation of available moisture content in the soil. In fact, the result of soil particle size distribution shows that it has a good bulk density which implies the high holding capacity of water. And we have an organic matter in general which is medium to high (table1) even particle size distribution and bulk density determine the distribution of macro pores and micro pores density are good in our study area (Table 3), all those factors influence our study are influencing our soil study area to retain water.No-tillage systems seemed to be more suitable for sustaining favorable soil porosity by preserving the elongated transmission pores that aid root growth. Since the porosity in both treatments was greater than 40%, they are unlikely to limit crop growth since they show no soil compaction, easy root penetration, proper aeration, and water preservation within the soil (Gachene*et al*., 2003).

5.12 Bulk density and particle density of different land management

The values of particle density of the soils studied are presented in table 3. The results show that the texture class of the studied soils was dominated by sandy loam and a little sandy clay loam. According to Hazelton & Murphy, (2007), the sand content is very high in the studied soil and there are no trends changes along topo sequence of studied area and the figure below shows that in general the value of particle density varies between 2.58 and 2.72 g/cm^3 while normal particle density for plant growth is 2.66 g/cm^3 (E.S. Marx, J. Hart, 1999). The possible causes of decrease of BD in the study area are organic matter addition in the field, if soils are wetter than field capacity, bulk density may increase. Growth of root, in general, starts to be restricted when the bulk density reaches 1.55 to 1.6 g/cm^3 and is forbidden at about 1.8 g/cm^3. Bulk density had a specific trend by increasing soil depth in the crest and mid-slope but recorded no specific trend in foot-slope. However, bulk density decreased from the crest to the foot-slope and had no significance among the physiographic positions. This is in concurrence with the works of (Aweto and Iyamah, 1993) in the soils of southern Nigeria. Also, some researchers (Gafar et al., 2004; Abrams et al., 1997) have reported similar findings on soil along topo sequence. The bulk density was found to be below the critical limit (1.75 – 1.85 g kg^{-1}) as recommended by SSS, (2006) for root penetration.

VI. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The assessment on impact of different land management on soil quality in Migina catchment using soil laboratory analytical methods was one direction of achieving this research. The physicochemical parameters already analyzed have shown that the land management practices have a positive impact on soil nutrient availability and also have positive effects in social-economic development of population and agricultural sustainability. Good establishment, well monitoring and evaluation of different land management practices are essential factors for land management sustainability and crop productivity.

The main objective of this research work was to analyze the impact of land management practices on soil quality in Migina Catchment at Akaboti Cell, Kansi Sector, Gisagara district, in southern province of Rwanda, with focus on physicochemical properties of soil, this work was done under different land management practices that are radical terrace, trenches, agroforestry, forestry, soil amendment and control or undisturbed land in order to know the best to be used for conserving our soil fertility status.

The laboratory results show that the soil texture was dominated by a sandy loam class, the soil bulk density varies from 0.96 to 1.44 g/cm^3 in general, the soil porosity ranges from 50.2 to 52.08 % in terraced land; 47.2 to 58.16 % in trenches; 53.8 to 63.87 % in agroforestry; 53.08 to 53.8 % in forestry; 56.39 to 58.9 % in amended soil and 45.9 to 51.84 % in the control (undisturbed land). The soil pH measured in water ranges from 4.73 to 5.14 for radical terraces land, from 5.79 to 5.29 for trenches; 6.29 to 5.79 for agroforestry land, 4.93 to 4.49 for forested land, 5.11to 6.34 for amended soil and 4.69 to 527 for control. The electrical conductivity is low in treatments ranging from 0.076 to 0.390%, The values of mineral Nitrogen measured in treatments were higher compared to control. Ammonium values range from2.55 to 7.24 mg/Kg while Nitrate values range from 4.36 to 28 mg/kg. Available P values were high in treatments compared to control.

The values of available P range from 8.55 to 17.10 ppm. The values of exchangeable bases were slightly high in treatments compared to control. Those values were generally low. Generally, the agro forestry land showed high nutrients values compared to the control and other treatments. From the results of this study, it is clear that the land management practices have generally a positive impact on soil properties.

6.2 Recommendations

- Considering the output of our research project we put forward the following

recommendations to be used for reinforcing land management practice and to mitigate the negative impact on the land degradation and soil fertility deterioration, so as to guarantee sustainability of land management in this study area.

- The government, agricultural institutions and other institutions involved in land management activities should invest more in research across the whole country in order to enable farmers to adopt appropriate soil fertility management practices in relation to both soil and water quality improvement.
- The government should provide qualified technicians who are able to establish sustainable land management practices especially terraces and trenches, to select improved seeds of trees species for agroforestry and forestry which is generating not only more organic material for producing sufficient organic matter but also retain material that may compromise downhill surface water.
- Farmers should be more sensitized by extension workers about new agricultural technologies such as agroforestry system which increase in soil organic matter in order to replenish the lost plant nutrient and to manage their land fertility sustainably as well as environment and also as source of multiple benefits,
- Farmers also must apply lime in order to reduce soil reaction acidity of this area, apply sufficient organic manure for improving soil nutrients needed by plant, microbial activity reinforcement and soil physicochemical parameters availability,
- Farmers should learn how to use rationally and efficiently both organic and chemical fertilizers and so that they increase soil productivity potential of their land.
- For the soil quality; waste management must be carefully considered because they are considered as a source of more toxic elements which may be harmful and so act for decreasing the soil fertility status. The acidic tolerant plants should be adopted to be grown in the studied area, if there is no other possibility to improve soil trend to be acidic such as lime application as usually done.
- It would be better if we could cover the whole country, but we didn’t get enough means and time for that purpose, so our study has been small scale oriented and just limited to Migina catchment. For that we invite other researchers to conduct deep research on the impact of land management practice by extending their research to all aspects of the complex issues on soil and Environments.

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